Monitored tracer experiment using the vadose zone experimental setup (VZES) for studying water and pollutant recharge processes in a brownfield

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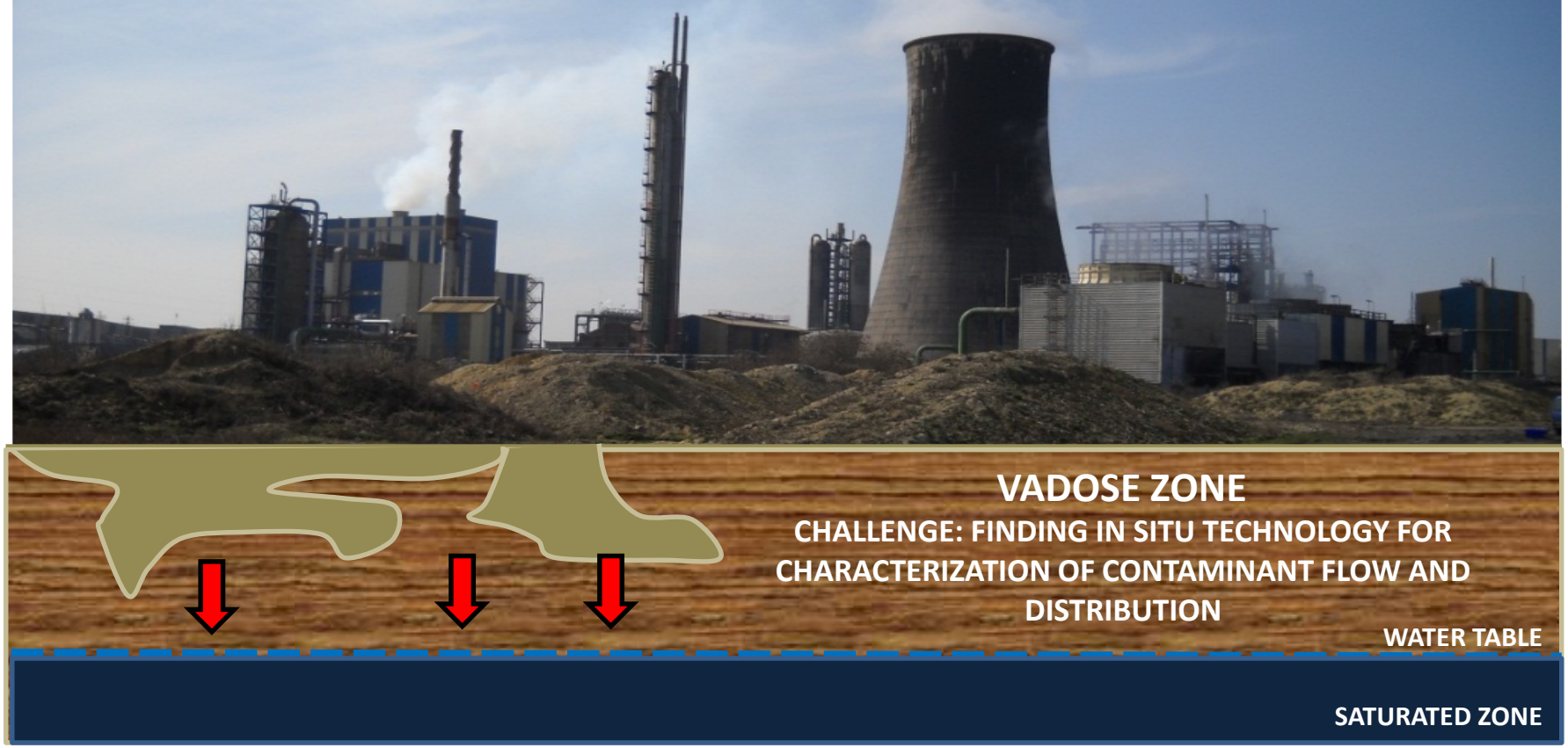
Université de Liège

ADVOCATE

MARIE CURIE ACTIONS

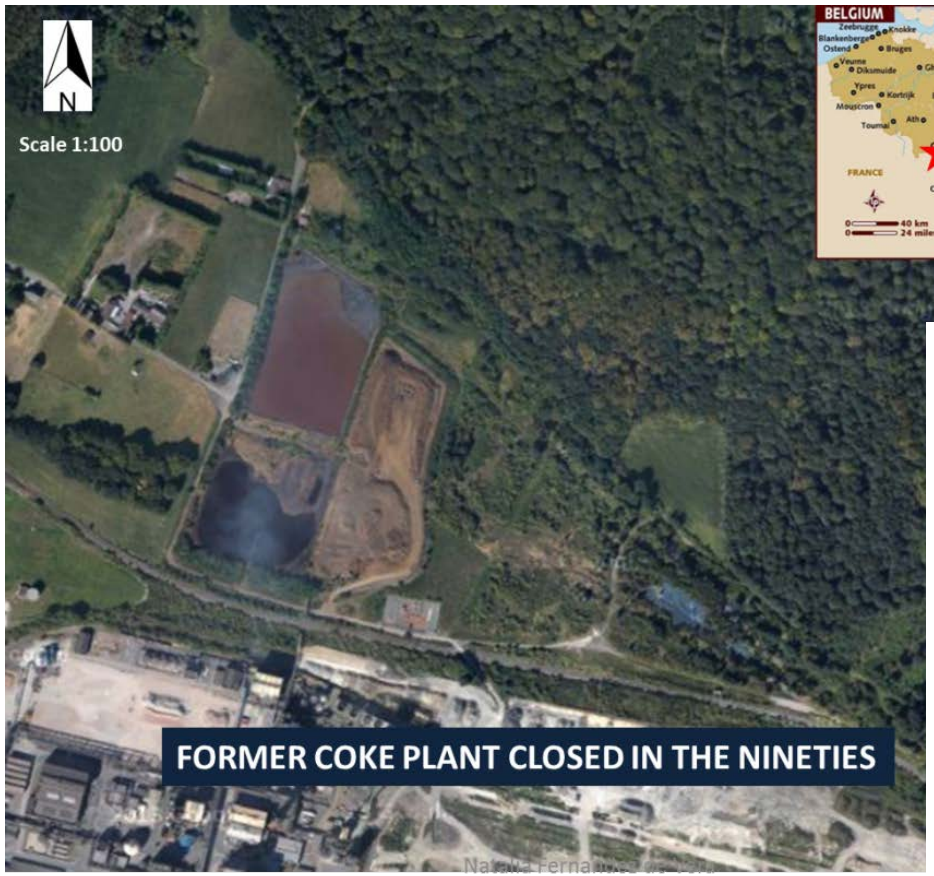
CONTEXT OF THE STUDY

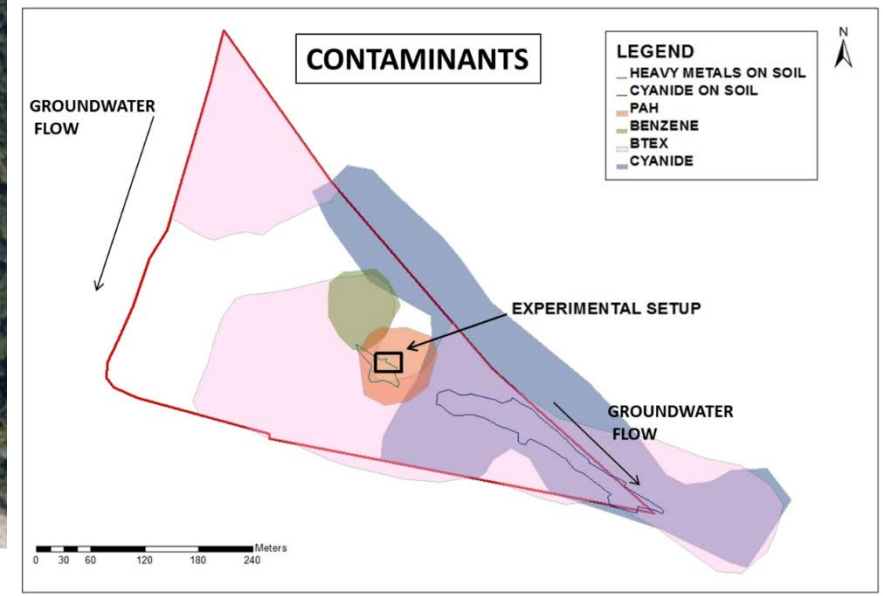
- The development of risk assessment and remediation plans requires a detailed understanding of transport of pollutants in the subsurface
- Subsurface characterization is challenging at industrial contaminated sites due to the presence of complex subsurface environments



INDUSTRIAL CONTAMINATED SITE: CARCOKE

- LOCATED OVER CRETACEOUS CHALK, SILEX AND MARLS DEPOSITS
- GROUNDWATER FLOW DIRECTION: N-Sn GROUNDWATER DEPTH APPROX 7m
- SOIL AND GROUNDWATER CONTAMINATED WITH CYANIDE, BTEX, PAH, HEAVY METALS





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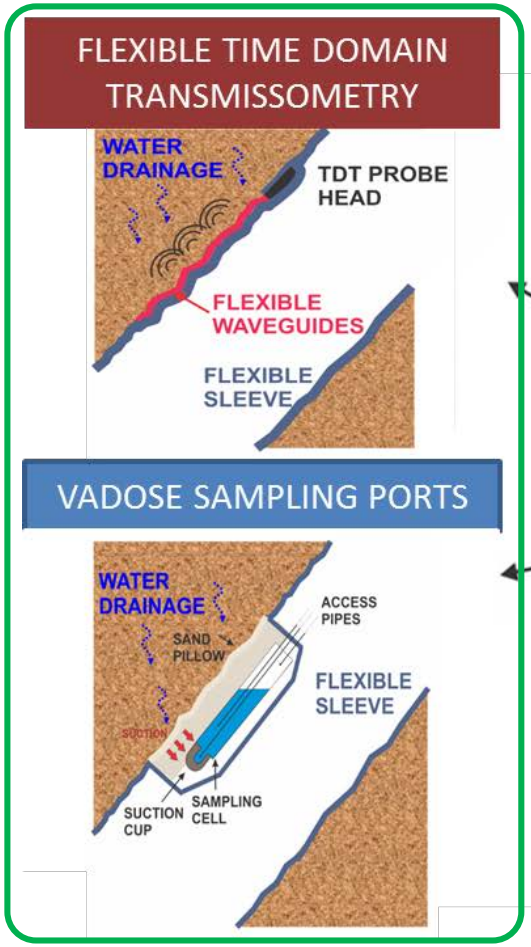
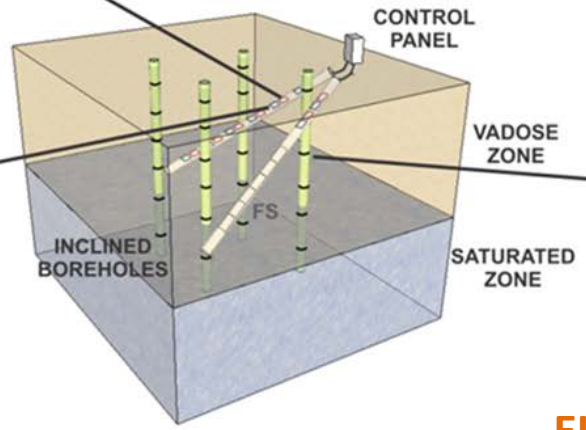
PREVIOUS VADOSE ZONE STUDIES AT THE CARCOKE SITE

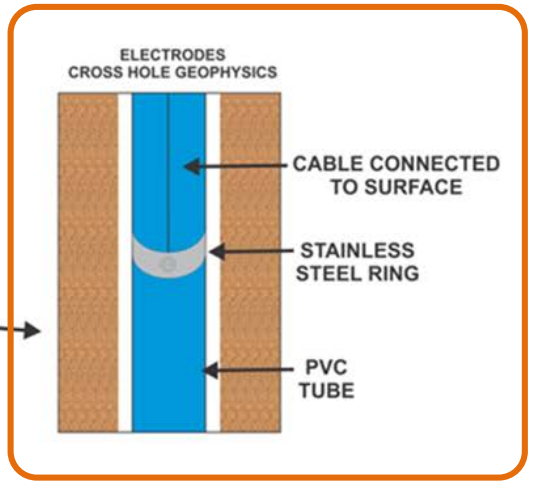
EXPERIMENTAL SETUP

1) VADOSE ZONE MONITORING SYSTEM



FLEXIBLE TIME DOMAIN TRANSMISSOMETRY (FTDR) : Monitoring subsoil water contents





2) GEOPHYSICAL SYSTEM

ELECTRODES IN BOREHOLES

Subsurface characterization with cross-borehole Electrical Resistivity Tomography (ERT) measurements

VADOSE SAMPLING PORTS (VSP)

Collect water samples from subsoil

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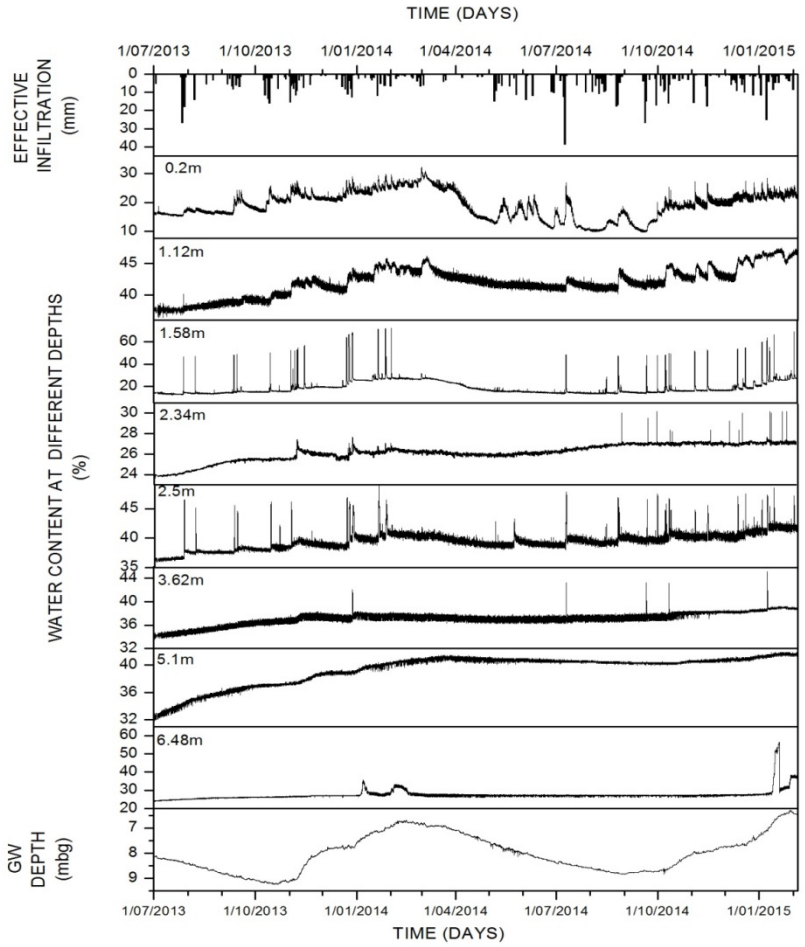
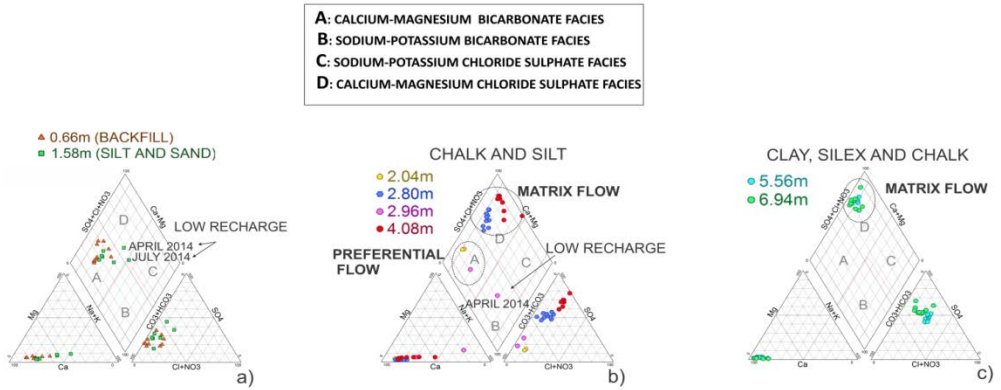
PREVIOUS VADOSE ZONE STUDIES AT THE CARCOKE SITE

NATURAL RECHARGE CONDITIONS

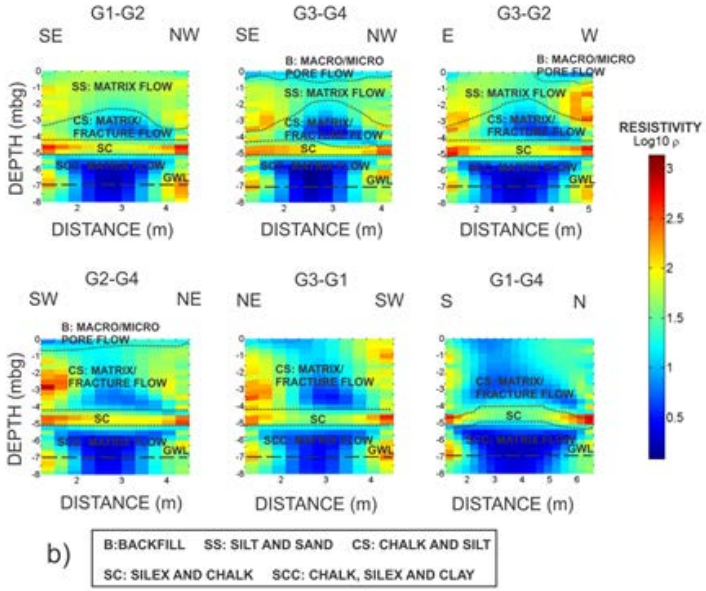
IDENTIFYING WATER FLOW MECHANISMS FROM WATER CONTENT SENSORS



IDENTIFYING CHEMICAL FACIES OF PORE WATERS ACROSS THE VADOSE ZONE



SUBSURFACE CHARACTERIZATION WITH GEOPHYSICAL METHODS

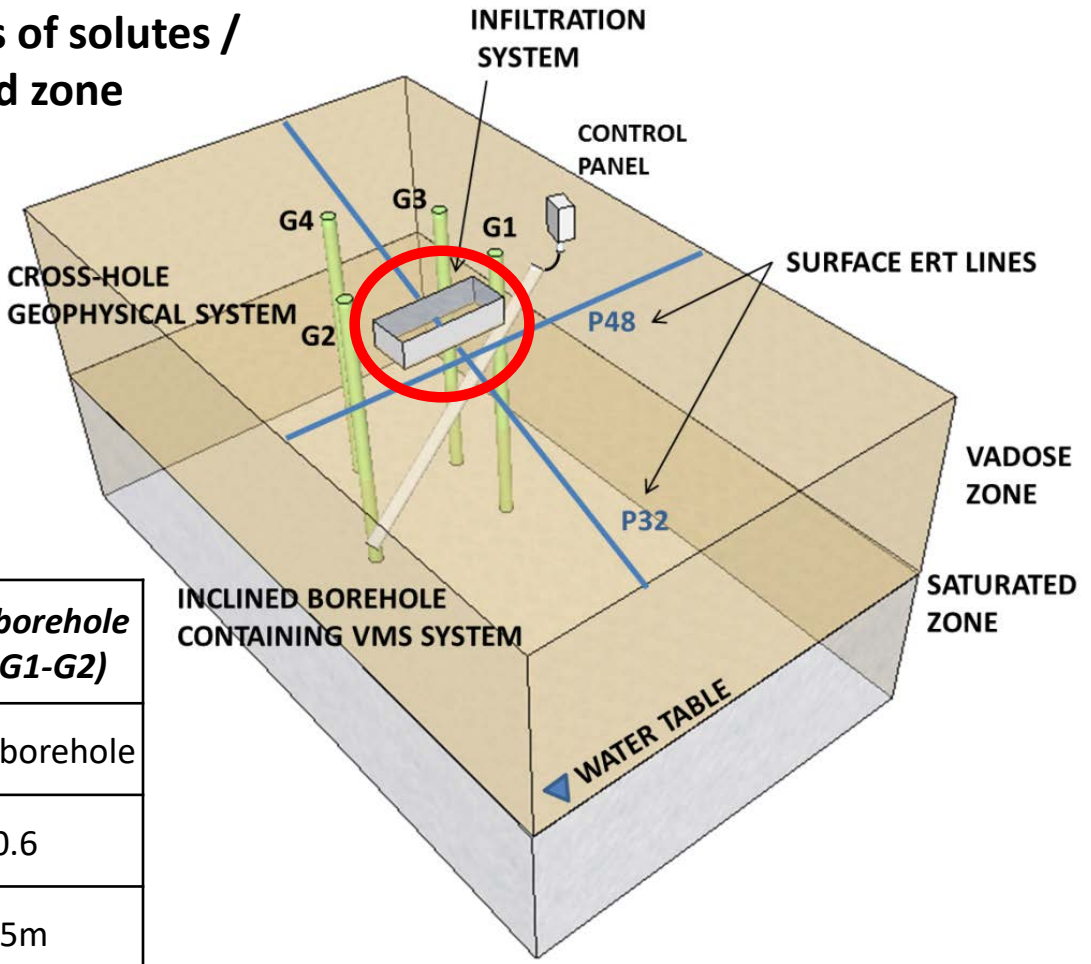


Fernández de Vera et al., IAH conference in Rome, sept. 2015
Fernández de Vera et al. 2016, HESS under revision

EXPERIMENTAL SETUP FOR A VADOSE ZONE TRACER TEST

Why a tracer experiment?
→ To better understand the dynamics of solutes / pollutants in this complex unsaturated zone

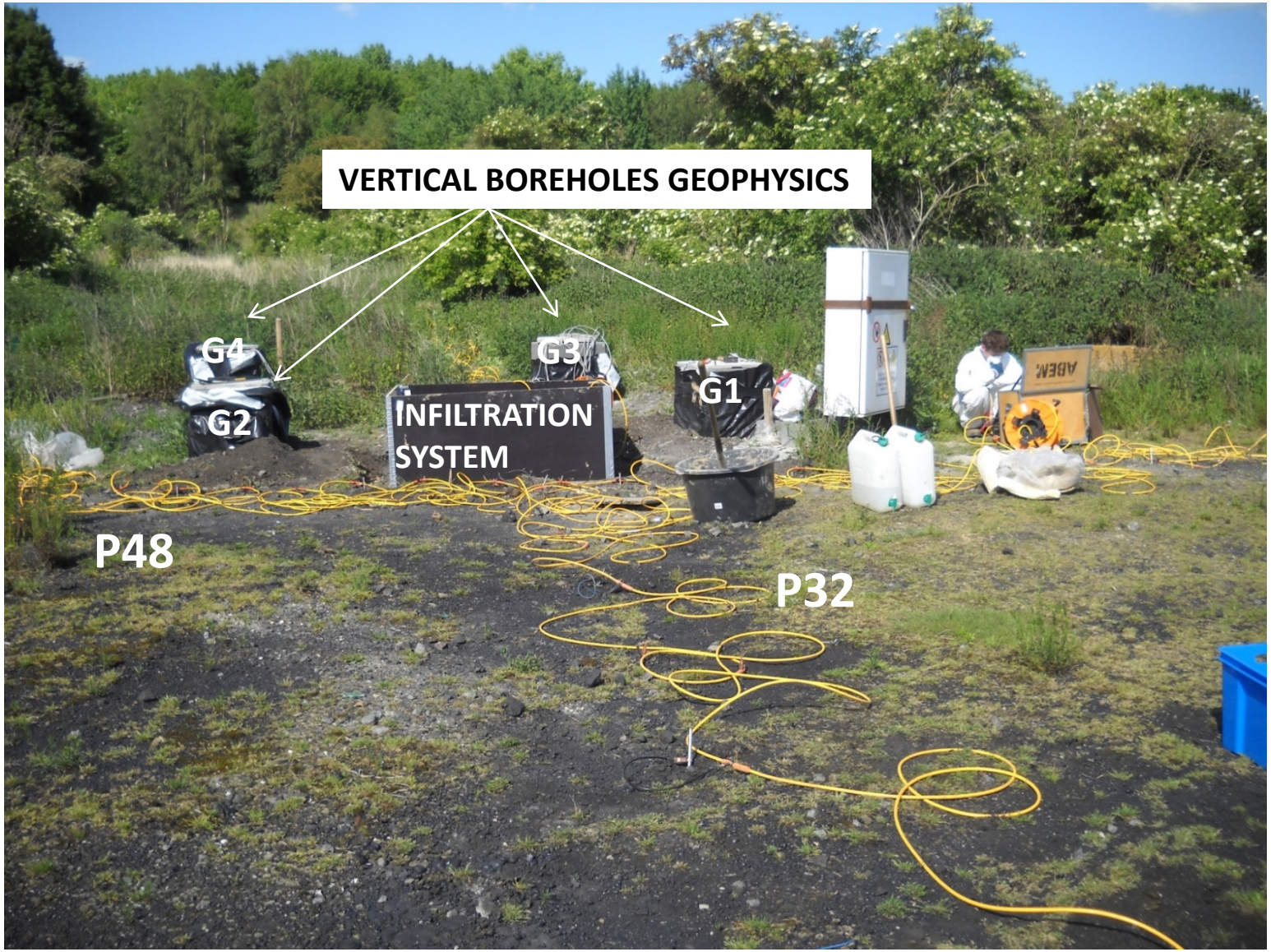
INSTALLATION OF AN INFILTRATION SYSTEM



GEOPHYSICAL SYSTEM:
SURFACE AND CROSS-BOREHOLE ERT

	Surface ERT P48	*Surface ERT P32*	*Cross-borehole ERT (G1-G2)*
Electrode number	48	32	24 per borehole
Electrode spacing (m)	0.4	1.25	0.6
Depth of investigation	4m	8m	15m
Array	Dipole-dipole	Dipole-dipole	Bipole-bipole (AM-BN)

EXPERIMENTAL SETUP FOR A VADOSE ZONE TRACER TEST



EXPERIMENTAL SETUP FOR A VADOSE ZONE TRACER TEST

TRACER SELECTION

HIGHEST ELECTRICAL CONDUCTIVITY OF SAMPLED WATER IN THE VADOSE ZONE: +/-1800 µS/cm

⇩

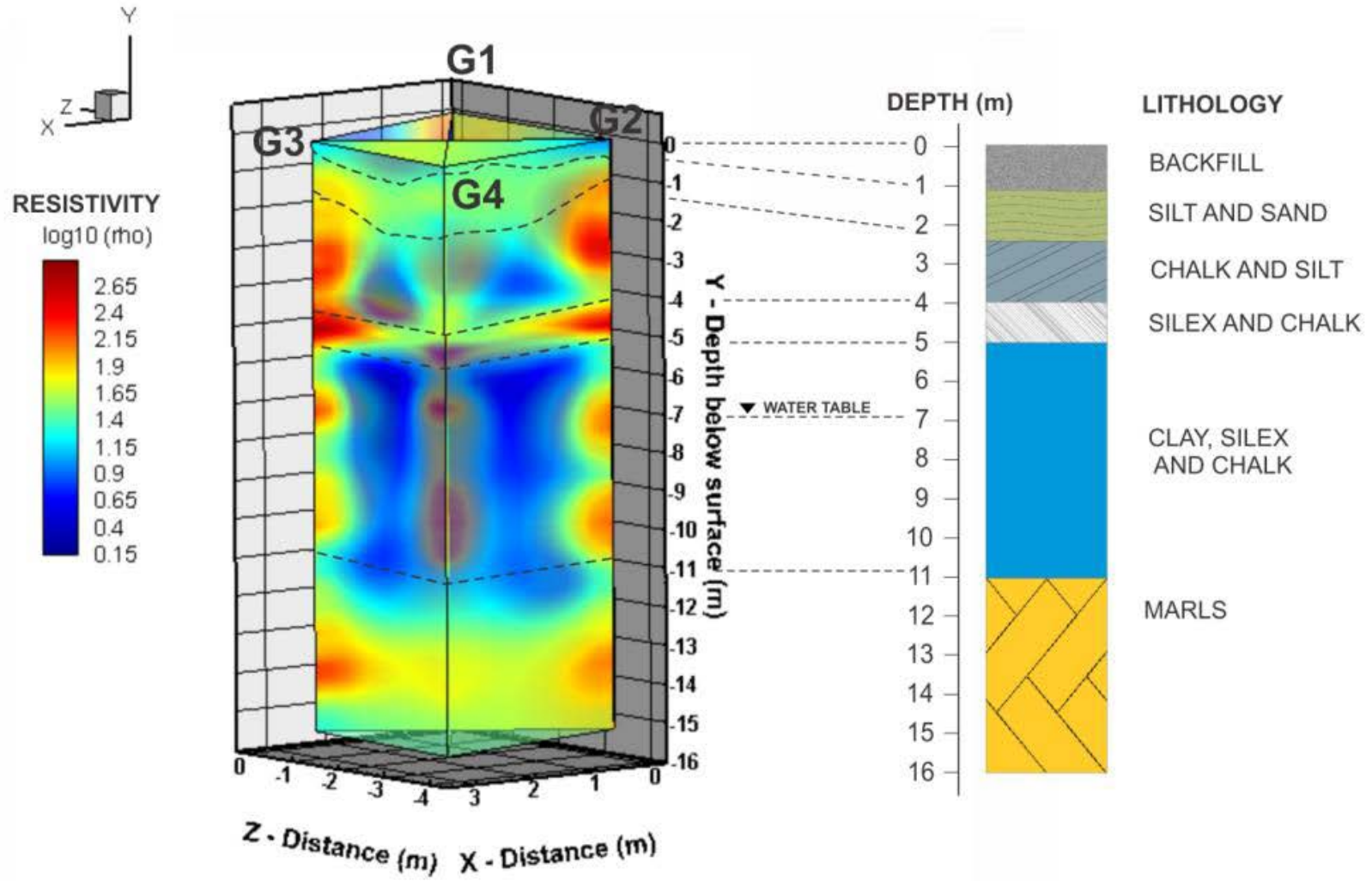
50Kg of $CaCl_2$ +2Kg of LiCl IN 600L OF WATER ELECTRICAL CONDUCTIVITY: 107000µS/cm

⇩

ENOUGH CONTRAST FOR TRACKING THE TRACER WITH GEOPHYSICS

RESULTS

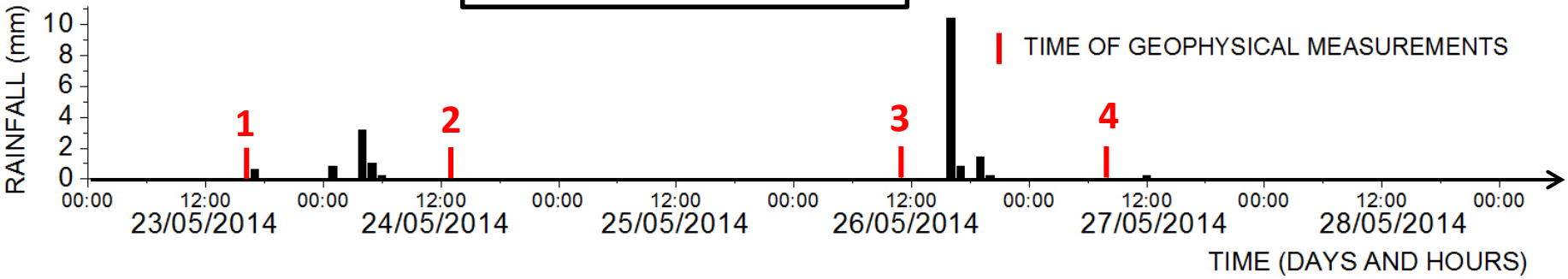
BACKGROUND IMAGES GEOPHYSICS

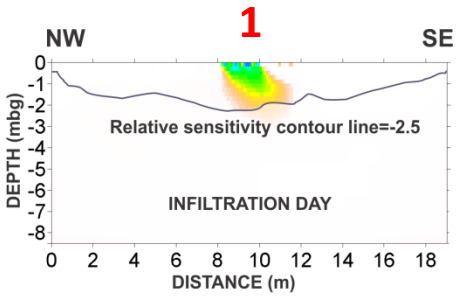


RESULTS

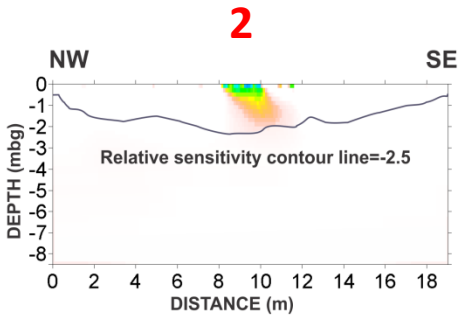
SHORT TERM MONITORING (5 DAYS): SLOW VERTICAL FLOW

SURFACE PROFILE P48



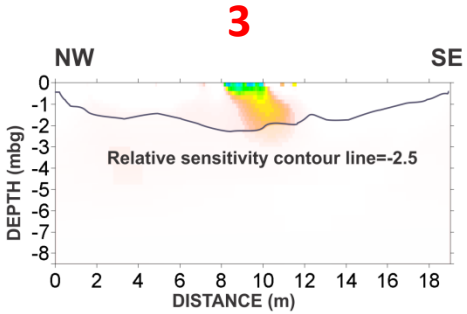


23/05/2014
16:48 pm



24/05/2014

Plume tail modified by rain events
(between image 1 & 2 & 3 & 4)



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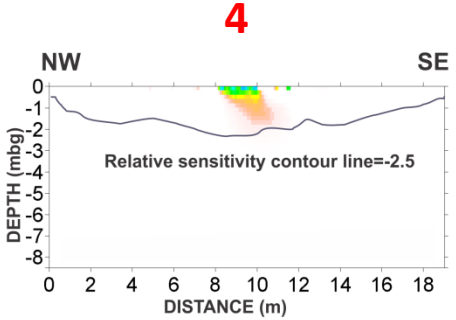

27/05/2014
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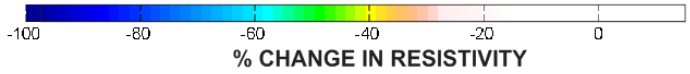
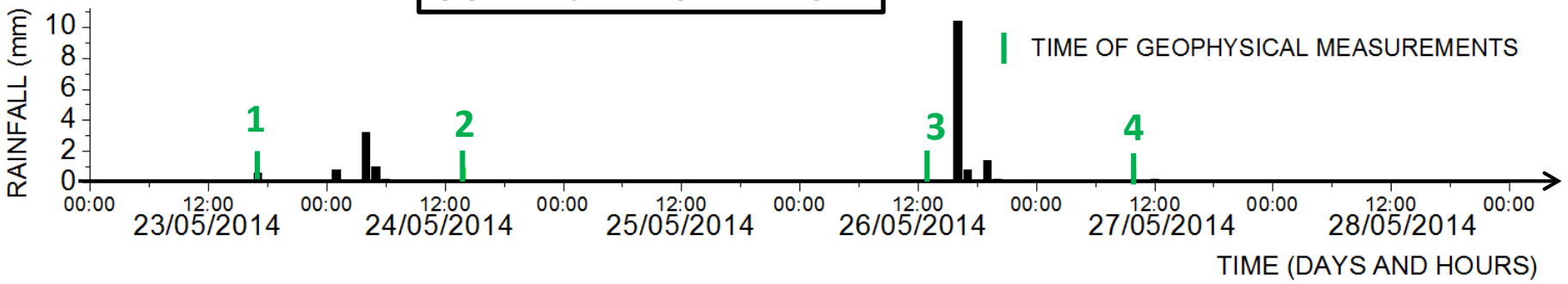


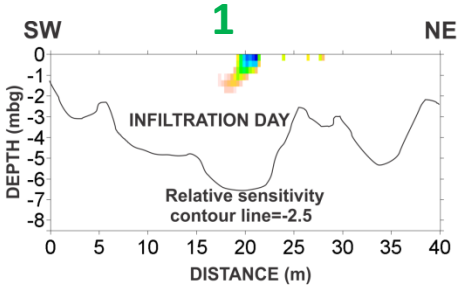
Threshold cutoff: 25%

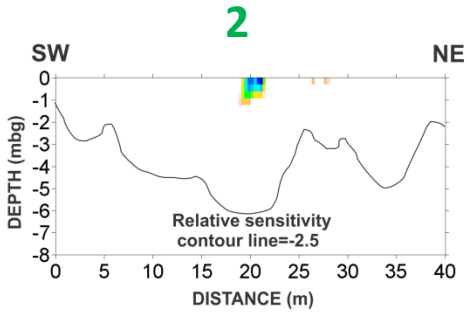
RESULTS

SHORT TERM MONITORING (5 DAYS): SLOW VERTICAL FLOW

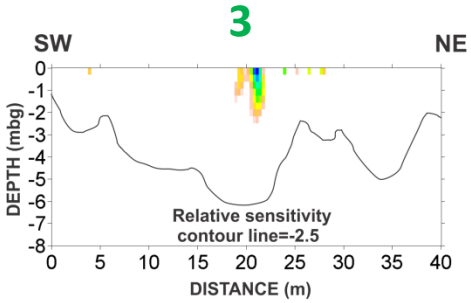
SURFACE PROFILE P32

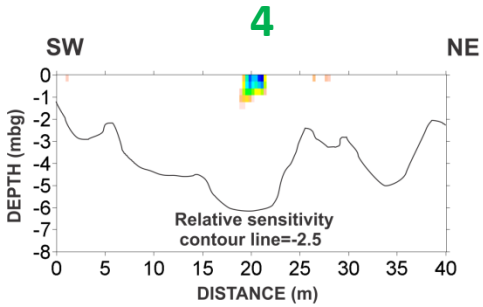






Plume tail modified by rain events
(between image 1 & 2 & 3 & 4)

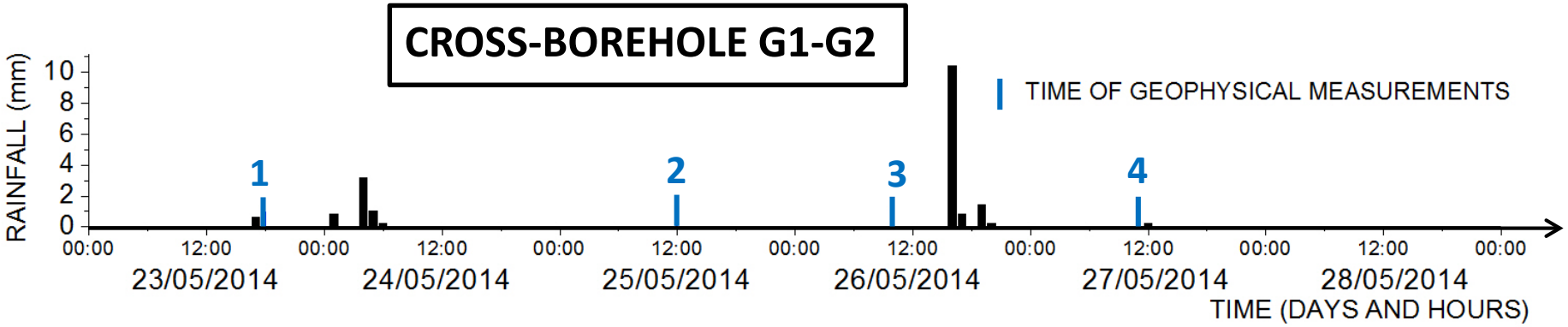


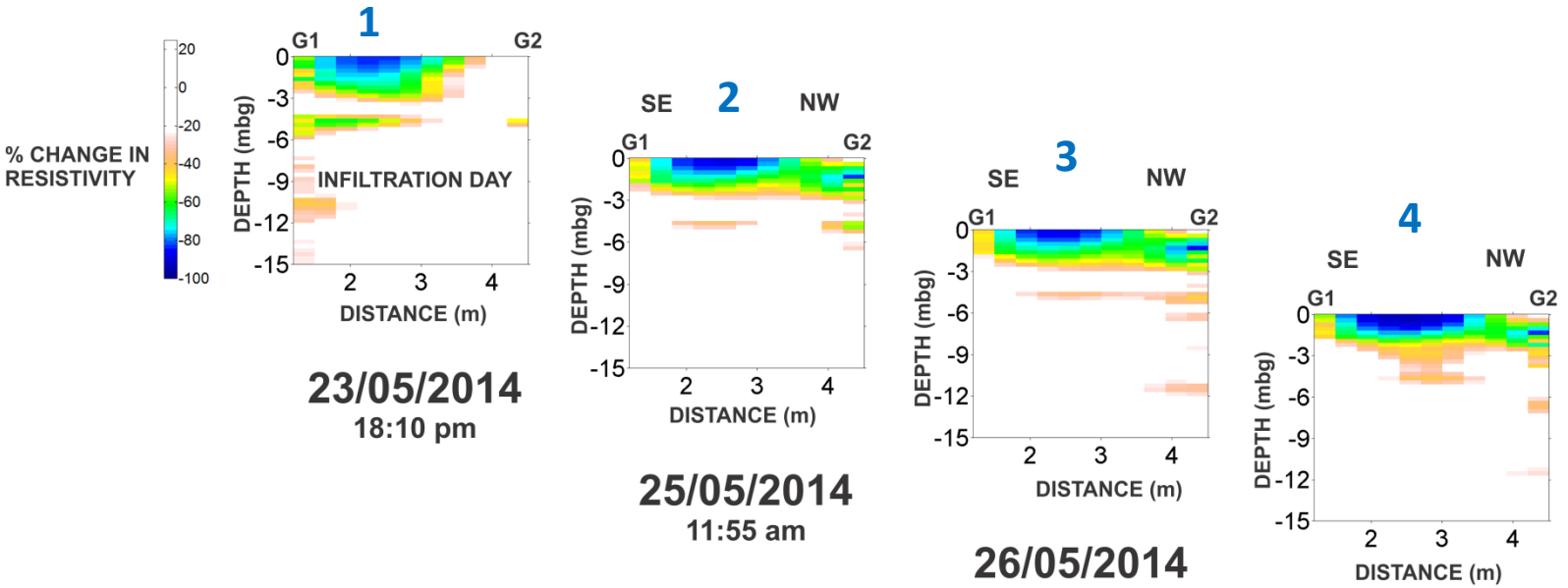


Threshold cutoff: 40%

RESULTS

SHORT TERM MONITORING (5 DAYS): SLOW VERTICAL FLOW





Threshold cutoff: 25%

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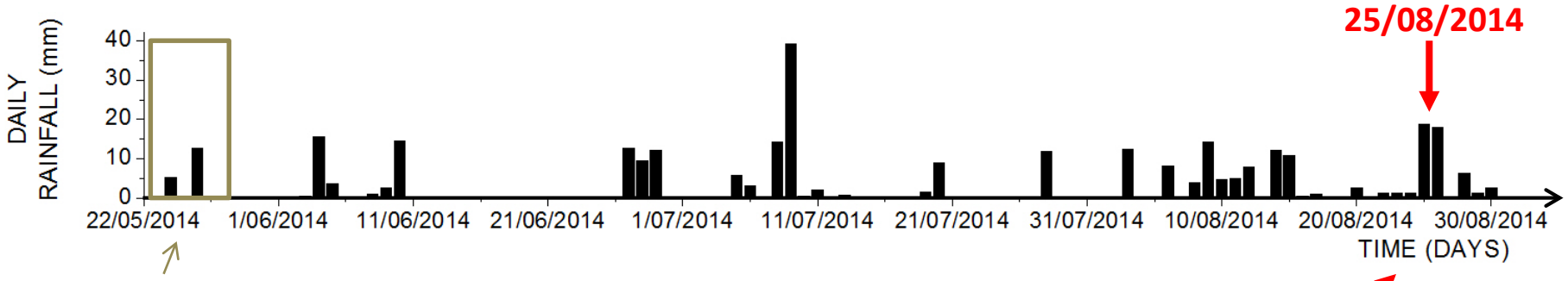
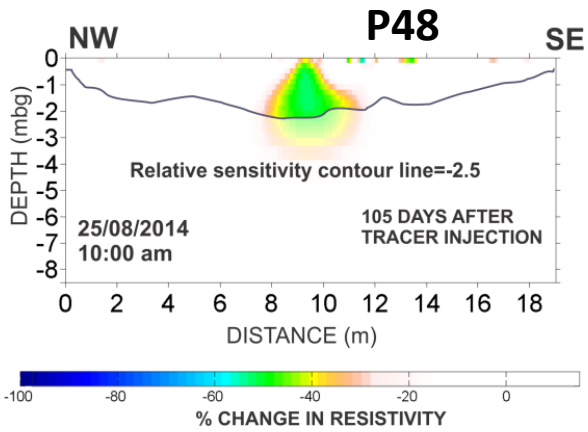
RESULTS

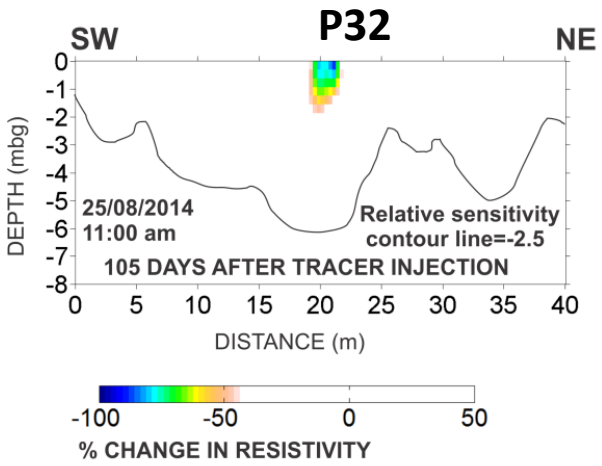
LONG TERM MONITORING (105 DAYS AFTER)

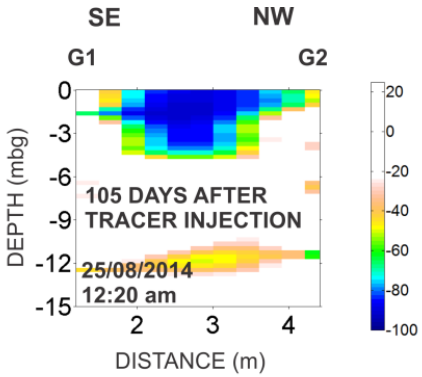


SHORT TERM
GEOPHYSICAL MONITORING (see 3 previous slides)

LONG TERM GEOPHYSICAL MONITORING







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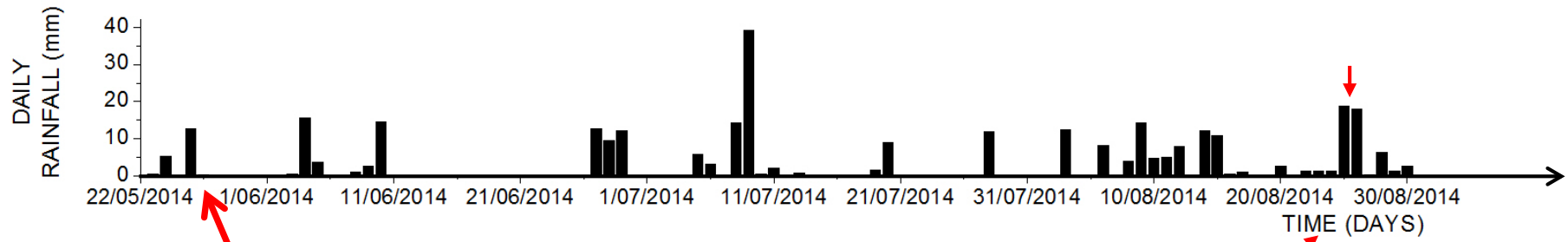
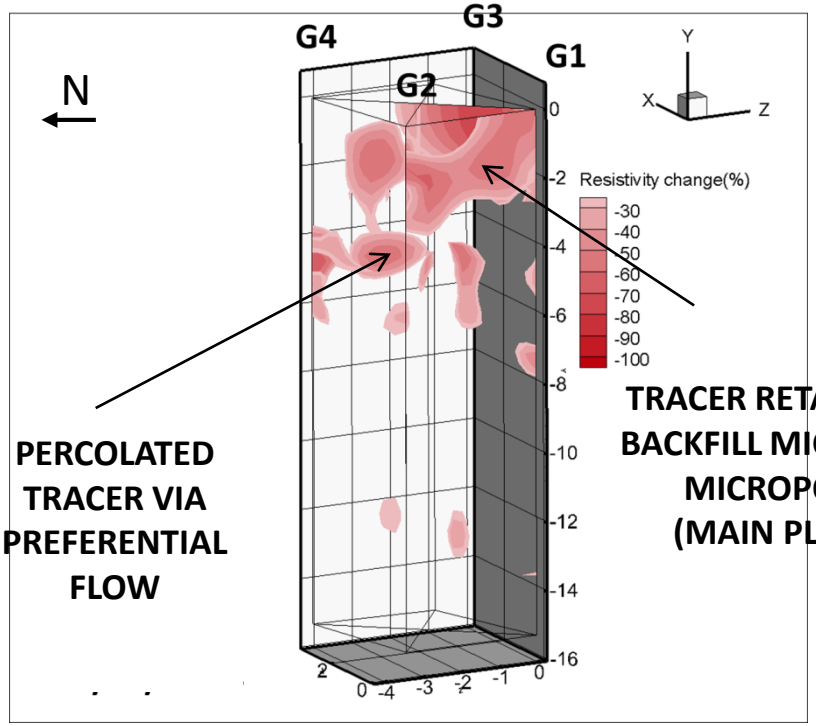
RESULTS

MEASUREMENTS G1 G2 G3 G4



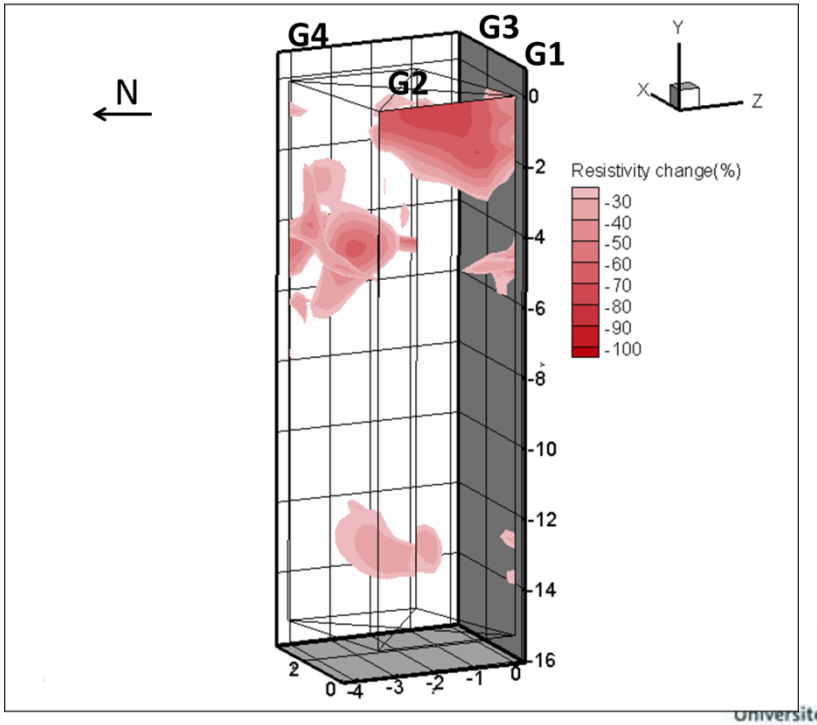
28TH MAY 2014



PERCOLATED TRACER VIA PREFERENTIAL FLOW

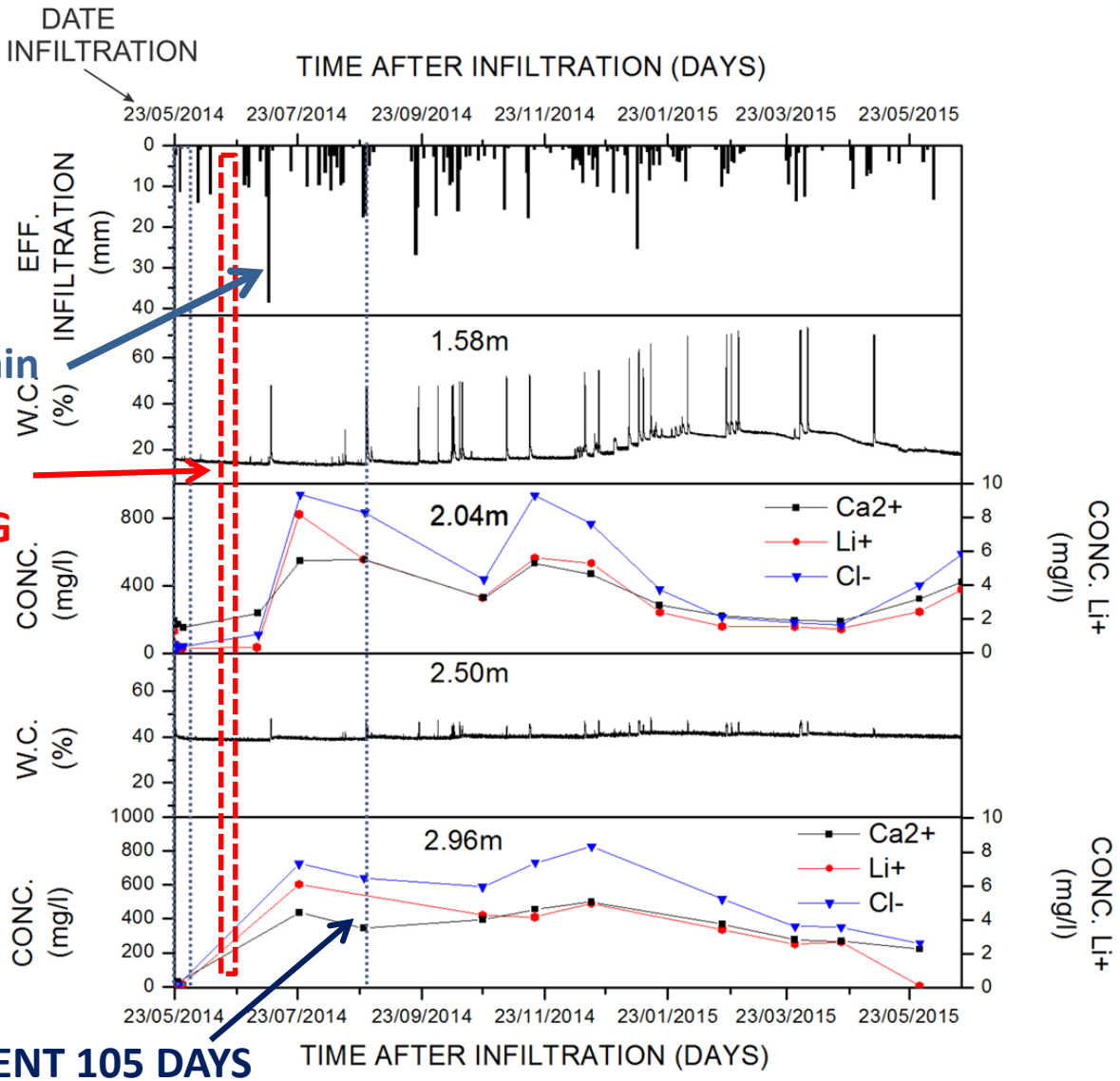
TRACER RETAINED IN BACKFILL MICRO AND MICROPORES (MAIN PLUME)

25TH AUGUST 2014



RESULTS

VMS MONITORING



38.6mm of rain

SHORT TERM MONITORING

MEASUREMENT 105 DAYS AFTER INJECTION

HIGH INTENSITY RAINFALL EPISODES ENHANCE VERTICAL TRANSPORT THROUGH FRACTURES AND MATRIX

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CONCLUSIONS

Main findings from field setup:

- ✓ **Confirmation of main infiltration / transport mechanisms:**
  - ✓ **Matrix flow through micropores**
  - ✓ **Preferential flow through macropores and fractures**
- ✓ **Transport in the absence of significant recharge episodes:**
  - ✓ **Slow infiltration of water and dissolved species through the effect of gravity across the subsurface**
- ✓ **Transport during significant recharge episodes:**
  - ✓ **Preferential flow is activated through macropores and fractures.**
  - ✓ **Fast transport of water and solutes across the vadose zone and tracer redistribution**

CONCLUSIONS

Consequences for pollutant leaching across the unsat zone:

- ✓ **Not just a simple infiltration mechanisms but a complex behaviour with initial infiltration, then redistribution and episodic leaching to deeper unsat zone during subsequent rainfall – infiltration events**

- ✓ **Such result questions "classical" conceptual model where infiltration is often assumed steady state with contaminant leach "gently" downwards.**
  Most probably, mass flux approaches (across VZ) would be better appropriate, with the idea to estimate an annual mass flux discharge to groundwater and not a concentration at the base of the vadose zone

THANK YOU

Research was funded by the European Community's Seventh Framework Programme (FP7/2007-2013 under grant agreement number 265063)

Link to video of the installation

http://www.ulg.ac.be/cms/c_3331470/fr/comprendre-la-pollution-des-eaux-souterraines

Science communication video

https://www.youtube.com/watch?v=bV54ZelpLf8

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Department of Applied Geophysics (University of Liège)